Chapter 10.
Final Project Configuration

This chapter further refines the preferred Denny Way / Lake Union CSO Control Project alternative and examines system hydraulics in detail, including how the system would operate under various rainfall and flow conditions. The final project configuration described herein is a refinement of the storage and treatment alternative (Alternative 3) described in Chapters 6, 7, 8, and 9. Alternative 3 was developed for the purpose of comparing the storage and treatment and treatment alternative with other CSO control alternatives and selection of the preferred concept. Minor differences exist between the configuration presented herein and Alternative 3 presented in the earlier chapters, however, the final project configuration is consistent with the Alternative 3 concept of storage and at-site treatment to control untreated discharges to one event per year. Each of the components of the system is described, and the results of hydraulic modeling are presented in order to predict the overall system performance. The chapter concludes with a summary of proposed National Pollutant Discharge Elimination System (NPDES) permit requirements for the project.

10.1 Overall System Operation

The Denny Way / Lake Union system has several modes of operation. System operation would be determined by the quantity of wastewater entering the system, the upstream and downstream conditions, and the tidal elevation. Each mode of operation, important variations, and the design storm are described below.

10.1.1 Nonstorm Events

Weir elevations and gate positions would be set so the planned improvements would have no influence on dry weather flows. The nonstorm event flows would continue to flow through the existing Central Trunk, existing Lake Union tunnel, and the existing Elliott Bay interceptor (EBI) as shown on Figure 10-1. Water surface elevations in these pipes, under dry weather conditions, are below diversion structure weir elevations; thus, no flow would be diverted into the planned facilities. This mode of operation would handle very small storms.

10.1.2 Tunnel Storage Mode

Storage mode is initiated as flow depth in the EBI rises to its maximum set point (80 percent full). This causes the diversion gates in the Denny regulator to close, which in turn signals the gates in the Lake Union CSO tunnel regulator to close, diverting flow to the Mercer Street tunnel.

When, as a result of higher system flows, the system pipeline water surface elevations rise to a point where they exceed the Denny diversion structure and the Central Trunk diversion structures' weir surface elevations, flow would begin to be diverted from these existing pipelines into the new facilities. The City's flow-splitting manhole would divert flow to the Mercer Street tunnel and the Lake Union Tunnel regulator. All flows diverted during the tunnel storage mode of operation would be conveyed to either the east or west portal of the Mercer Street tunnel, where they would be stored until capacity exists in the Elliott Bay interceptor for conveyance to the West Point Treatment Plant. Figure 10-2 shows the facilities in

Figure 10-1.
Non-Storm Flow Schematic

8-1/2 X 11

use during the tunnel storage mode of operation. Tunnel storage would be required during any storm that currently results in an overflow at the Denny or Dexter regulator stations, or from the City of Seattle's south Lake Union CSO project.

In the tunnel storage mode, flow entering the pump station from the Elliott West CSO pipeline and EBI would be conveyed by gravity to the tunnel.

10.1.3 CSO Treatment Mode

Treated discharge would occur when the Mercer Street tunnel approaches its capacity and there is insufficient Elliott Bay interceptor conveyance capacity to accept additional flows. The wet well water surface level will control the water surface elevation in the tunnel. Figure 10-3 shows the facilities in use during the CSO treatment mode. When this occurs, the Lake Union tunnel regulator gate remains closed and all South Lake Union flow is routed to the Mercer Street tunnel.

As flow is pumped from the wet well, the water level in the channel will rise until the flow passes through a weir with mechanically cleaned horizontal or vertical screens. Flows passing through the screens will discharge into the pump effluent channel. Sodium hypochlorite will be injected at the end of the effluent channel, and the chlorinated effluent will flow by gravity through the Elliott West effluent pipeline. Chlorine contact time will be achieved during conveyance through the effluent pipeline to the Elliott West outfall, where the effluent will be dechlorinated and discharged.

CSO treatment peak capacity is planned for 250 mgd, which is expected to handle Design Storm 6, the one-event-per-year storm. Storms that cause flows in excess of 250 mgd will require the system to operate in “overflow mode,” as described below.

10.1.4 Overflow Mode

Design Storm 6, is the design basis for the Denny Way / Lake Union CSO control system improvements. Untreated overflows will occur during storms greater in intensity and length than Design Storm 6. Once all downstream conveyance capacity, upstream and tunnel storage capacity, and treatment capacity have been exhausted during those larger storms, untreated discharge will occur at the Denny regulator station. As the Elliott Bay interceptor fills, the water surface elevation in the interceptor will rise until it reaches the overflow weir elevation. Discharges would also occur via the existing overflow weir for the Lake Union tunnel and the existing weir and flap gate assembly for the Denny local sewer. If these facilities are insufficient to relieve the excess flow, the water surface elevation would continue to rise until it reaches a preset level, at which time the overflow gates in the Denny regulator station would open to more quickly relieve the system. The overflowing wastewater would be discharged through the Denny Way CSO outfall extension at a depth just below the water surface elevation in Elliott Bay. Flows discharged through the Denny Way CSO outfall extension would not receive floatables control or disinfection. However, flows being discharged through the Elliott West outfall would continue to receive floatables control and disinfection. Figure 10-4 shows the facility operation during storm events in excess of Design Storm 6.

10.1.5 Tunnel Drawdown Mode

Following any storm event large enough to cause diversion to the Mercer Street Tunnel, stored flows remaining in the facilities would be pumped to the Elliott Bay interceptor. Figure 10-5 shows the facilities in use during the drawdown mode. The EBI will be able to accept CSO flows and tunnel drawdown mode will begin when flows at West Point are below 300 mgd.

10.1.6 Emergency Mode

Should power failure occur during a storm event, the facility will be in the Emergency Operations Mode (Figure 10-6). The wetwell gate will be open and the pump effluent channel will be closed. The gate at the Lake Union Regulator will remain in the position it was when the failure occurred. The emergency generator will supply power to controls, lights, sump pumps, and the sluice gates during the power failure. When the storage capacity in the tunnel is exceeded, the water level in the wetwell will continue to rise.

Power reliability is discussed in more detail in section 10.3.5. The probability of a power outage during a storm event is low, ranging from once in ten to once in 300 years.

10.2 System Hydraulics

The proprietary software package XP-SWMM was used to develop the Denny Way /Lake Union CSO Control Project hydraulic model. The model is based on the USEPA Stormwater Management Model (USEPA-SWMM), that allows evaluation of the effects of backwater, surcharging, storage, pumping, and weirs under both open channel and pressure flow conditions. Model output includes peak hydraulic grade lines and peak flows at points throughout the project.

10.2.1 Hydraulic Assumptions

The primary assumptions in the modeling include inflows to the system, friction and minor losses, pump station operation, and tide levels. Inflows to the system were received from King County. The remaining assumptions are discussed below.

<u>Friction and Minor Losses.</u> Friction losses are based on Manning's equation. A Manning's n of 0.013 has been assumed for concrete pipe. For the brick portion of the Lake Union tunnel and the outfall, an n of 0.015 was used. Minor losses of 0.1, 0.2, and 0.3 were assumed for 30, 45, and 90 degree bends, respectively. Exit, entrance, and drop manhole losses were assumed to be 1.0, 0.5, and 1.5, respectively. Flap gates and duck bill losses were determined from the manufacturer's curves.

<u>Pumping Station.</u> XP-SWMM is not capable of modeling the variable-speed pumps in the pump station, nor can it model all pumps starting at the same elevation. Therefore, the assumed condition in the model is constant-speed pumps that are

turned on in sequence with 1-inch elevation difference between successive pump starts. Losses through the pumping station include the weir, Parshall flume, and other minor losses incorporated into the pump curve model input.

Tide Levels. Since there is little likelihood that peak runoff events would occur at the same time as the highest tide of record, the maximum annual high tide (107.13), was used in the model. An adjustment was made to account for the difference in density between seawater and combined sewage.

10.2.2 System Flows

System flows enter the system from the Lake Union area, from the Denny Way area, and from the Elliott Bay interceptor. Effluent flows are those which are pumped back into the Elliott Bay interceptor or are discharged out the proposed Elliott West outfall or the Denny Way CSO outfall extension. The following paragraphs describe how those flows have been estimated for this project.

Design Storm 6, a once-per-year storm, was chosen as the basis of design for the final Denny Way/Lake Union project to coincide with Ecology's requirement to control CSOs to no more than one untreated discharge per year. Treatment and pumping facilities within the project have been sized to meet project goals during Design Storm 6. The west flow stream includes overflows from the Elliott Bay interceptor and flows from the Denny regulator via the Elliott West CSO pipeline. Overflows from the Elliott Bay interceptor are subject to control at the Interbay pump station.

Figures 10-7, 10-8, and 10-9 show the Design Storm 6 influent hydrographs for flows to the west end of the Mercer Street tunnel, flows to the east end (south Lake Union CSO pipeline, Lake Union tunnel CSO pipeline, and Central Trunk CSO pipeline), and total influent flow, respectively. Figure 10-10 is an effluent hydrograph for Design Storm 6, which shows the flow discharged to the Elliott Bay interceptor from the Mercer Street tunnel and the flow to be disinfected and released to Elliott Bay. The model assumes the Interbay pump station is controlled to keep peak flows at West Point from exceeding 440 mgd.

In addition to Design Storm 6, the results from an especially high-intensity storm that occurred November 3, 1978, were used to examine peak hydraulic capacity. The highest 10-minute, 30-minute, and 60-minute overflow rates for all storms in the County's 19-year simulation occurred during the simulation of that storm.

10.2.3 Hydraulic Model Results

The hydraulics of the Denny Way/Lake Union CSO Control Project system have been evaluated for the following design storm conditions:

- Design Storm 6 with Interbay pumping at 133 mgd

- November, 1978 storm with no pumping at Interbay
- November, 1978 storm with no pumping at Interbay or Denny Way CSO pumping station

Tables 10-1 and 10-2 summarize peak hydraulic grade line elevations and peak flows throughout the project.

10.2.4 Hydraulic Profile

The hydraulic profile for the system during Design Storm 6 and the November 1978 storm under emergency conditions is shown in Figure 10-11. Peak flow rates for system components are provided as well as peak hydraulic grade lines for the design storms. Flow rates and grade lines are all based on a fully dynamic model that evaluates system hydraulics accounting for backwater, surcharging, losses, storage, and pumping. The final modeling of the system will be performed during final design. Final modeling will include fine-tuning of the model adjacent to the Denny Division Structure and Regulator.

10.2.5 Treated CSO Discharge Volume and Frequency

During development of this Facilities Plan, King County made modifications to its hydraulic model to perform simulations of the entire network over extended periods of rainfall. These modifications permit simulations over years of rainfall data with which to extrapolate statistical measures of CSO control facilities performance. King County performed simulations of the sewer system, including the Denny Way/Lake Union CSO Control Project, using actual rainfall data for the period from July 1, 1978, to June 30, 1997. The simulations provide a continuous record of the system over this period. The results of the simulation are described in the following sections.

Alternative analysis described in earlier chapters estimated the inflow and discharge volume and frequency using the results from simulations of seven historical design storms. The continuous simulations performed recently provide a better means of estimating system performance. The following paragraphs describe the results of the long-term analyses. Events in this analysis are defined as discharges, either to the tunnel or to Elliott Bay, that are separated by at least 48 hours without discharge. This is in accordance with Ecology's permit for Carkeek Park, and in accordance with a statistical analysis prepared for King County under the 1995 CSO Update Project (Task 16.01 Technical Memorandum, CSO Event Definition, Brown and Caldwell, August 30, 1996).

Table 10-1.
Peak Hydraulic Grade Line Elevations

	Design Storm 6		November 1978
	Interbay 133 mgd	**Interbay 0 mgd**	**Emergency**
Valley Street Connection	107.71	109.32	113.4
Mercer Street Tunnel	97.99	108.25	112.16
Central Trunk Diversion Structure	134.54	136.54	136.54
Lake Union Tunnel Regulator Station	113.55	114.74	114.74
Lake Union Tunnel at Western	108.42	111.24	114.2
Denny Diversion Structure	105.59	110.72	113.15
Denny Regulator Station	96.85	108.39	110.75
Elliott Bay Interceptor Manhole	102.3	108.6	110.99
Elliott Bay Interceptor Control Structure	99.36	108.57	111.81
Elliott West Effluent at Flume	127.73	131.67	NA
Effluent Pipeline Transition Structure	112.93	117.43	109.06

Table 10-2.
Peak Flows, cfs

	Design Storm 6		November 1978
Location	**Interbay 133 mgd**	**Interbay 0 mgd**	**Emergency**
South Lake Union CSO Pipeline	56	120	120
Central Trunk Diversion Structure	28	86	86
Lake Union CSO Pipeline	90	179	174
Lake Union Tunnel	53	101	94
Elliott West CSO Pipeline	105	115	-50
Elliott Bay Interceptor	124	238	-235
System Drain	288	344	-249
Elliott West Effluent Pipeline	406	385	97
Elliott West Outfall	406	385	97
Denny CSO Outfall	0	265	608

Annual Average Flow Conditions. The long-term simulations have indicated that the multiplying factors developed in previous work that are applied to design storm volume (see Chapter 8, Table 8-2) are somewhat in error when applied to discharge from the tunnel. Compared to the results of the continuous simulations, these factors underestimate the inflow volume and the discharge volume. For the 14-foot to 16-foot tunnel diameter, the annual estimated inflow volume, discharge volume, and discharge frequencies are shown in Table 10-3. The untreated CSO volume that would otherwise overflow to Elliott Bay or to Lake Union without the Denny Way/Lake Union project would be reduced by almost 99 percent by the new facilities.

Table 10-3 shows untreated overflow events for both the Elliott West facilities and Dexter Regulator. The model predicted several small overflows at Dexter (less than 0.1 MG) that are not included in the table. Analysis of these small events indicates that they involve an operational issue associated with the gate movement and the overflow weir elevation. Optimizing the initial gate position and raising the overflow weir elevation can eliminate these small overflows at Dexter. The long-term average shown in Table 10-3 corresponds to the long-term average annual rainfall of 36-inches. This is also shown by the vertical lines on Figure 10-12 and 10-13.

The inflow and treated discharge volumes are plotted as functions of annual rainfall depth in Figure 10-12. Figure 10-13 presents the annual number of treated discharge events plotted against annual rainfall. Envelopes of expected frequency and volume are also shown. For the range of rainfall depths encountered in Seattle and the range of intensities encountered, the system can be expected to discharge treated effluent to Elliott Bay from 1 to 30 times per year.

Individual Discharge Events: The model results indicate that 247 individual discharge events (discharge to Elliott Bay through new outfall) would have occurred in the 19-year period ranging in volume from 0.1 to 167 MG. Ninety percent of the individual events are less than 50 MG. The frequency distribution of individual event volumes is shown in Figure 10-14. This figure shows the number of events per year expected to equal or exceed a given volume. The discharge volume expected to be equaled or exceeded once per year is about 64 MG. Understanding the peak flow conditions is necessary to ensure that the pump station is sized to meet the design criteria of no more than one untreated discharge per year. Figure 10-15 shows the exceedence frequency of peak flows at the pump station from King County's 19-year hydraulic model simulation. The figure shows that the design peak effluent flow of 250 mgd is equaled or exceeded about once per year. Thus, the pump station design figure of 250 mgd is appropriate. The risk of effluent pumping capacity being too small to meet the once per year untreated discharge criteria in the future can be reduced by leaving space in the pump station to add one additional pump if found to be necessary in the future.

The peak flows shown on Figure 10-15 are potential flows that could occur, assuming that all potential influent flows were conveyed to the tunnel. Peak effluent flows in excess of 250 mgd that are shown on Figure 10-15 would discharge out the existing Denny Way CSO outfall. The hydraulic model simulation did not restrict influent flows. Thus, the simulations likely produced peak effluent flows that are higher than physically possible. Examination of the model configuration indicated that flows from City of Seattle overflow weirs along the Alaska Way interceptor were allowed to enter the model without overflow. This adds as much as 60 mgd to the highest peaks shown on Figure 10-15. In addition, there may be limitations on the maximum rate at which stormwater can enter the system through catch basins, further reducing the potential peak flows below the maximums shown on Figure 10-15.

Monthly Flow Conditions. The volume and frequency of discharges vary from month to month. It is necessary to understand the monthly average discharges for effluent dilution calculations. Figure 10-16 presents the estimated average and range of treated discharges to Elliott Bay for each month of the year. Depending on the rainfall conditions, discharge frequency may range from zero to five per month, with the highest frequencies occurring in the October to February period.

Figure 10-17 presents a plot of the average and range of monthly volume discharged in million gallons per day. The averages shown are the sum of all discharge volumes that occurred during the month, divided by the number of events during the month on which discharge occurred. The average monthly volumes are generally below 30 mgd--the exceptions being associated with the largest rainfall events on record. The highest monthly averages are associated with the largest rainfall events, events that may occur once in 5 years or even less frequently. These may be the only discharge events that occur in a given month, so the average flow is equal to the volume from the single event for that month. These large, infrequent values are not representative of normal conditions to be encountered. Accordingly, Figure 10-18 was prepared to show the frequency distribution of expected monthly average discharges. This figure indicates that a volume of about 45 mgd is expected to be equaled or exceeded once per year (85th percentile). In addition, the flow equaled or exceeded four times per year (50th percentile) will be below 10 mgd, based on results from the 19-year model simulation.

10.3 Configuration of Project Components

The preferred alternative configuration was developed in the Draft Denny Way/Lake Union CSO Control Facilities Plan (May 1997). Since the preliminary draft plan was prepared (May 1997), three design teams were selected and work began on the detailed predesign. During predesign, the original preferred configuration was modified. The modified configuration, including the south Lake Union conveyance facilities, is presented in the following section. The Denny area conveyance facilities, the Mercer Street tunnel, the Elliott West CSO control facility, the new outfall and existing outfall extension, and the Valley Street Connection are also described. The facility dimensions in the text take precedence over the dimensions shown on graphics.

10.3.1 South Lake Union Conveyance Facilities

The south Lake Union conveyance facilities would connect City of Seattle interceptors in the east Lake Union area to the new Mercer Street tunnel and provide a means of diverting storm flows from the existing Lake Union tunnel to the Mercer Street tunnel as well. A connection between the Central Trunk sewer and the Mercer Street tunnel would also be provided so wastewater that would otherwise overflow at the Dexter regulator station could be diverted into the new storage tunnel.

The south Lake Union conveyance facilities include:

- The Lake Union Tunnel regulator station.
- The Lake Union Tunnel CSO pipeline.
- The south Lake Union CSO pipeline.
- The Central Trunk diversion structure.
- The Central Trunk CSO pipeline.

South Lake Union conveyance facilities are shown on Figures 10-19 and 10-20, and are more fully described below. The invert elevations of the pipelines may be deeper than those shown. Deeper pipelines are being considered to avoid tunneling through debris in the fill in the upper soil strata and to simplify construction sequencing. Design criteria for the pipelines as they are currently designed are listed in Table 10-4. Final sizing will be determined during final design.

Table 10-4
Design Criteria Table for South Lake Union Pipelines

Pipeline	Diameter	Slope	Full Pipe Velocity (ft/s)	Flow* (mgd)	n-value
Lake Union Tunnel CSO Pipeline	72-inch**	0.0219	3.2/6.2	58/116	0.013
South Lake Union CSO Pipeline	72-inch**	0.0097	2.0/4.2	36/78	0.013
Central Trunk CSO	72-inch**	0.0224	N.A.	18/56	0.013

*XX/YY where XX=Design Storm 6 Flows, YY=November 1978 Flows
**The actual tunnel diameter may be 72-inches to 84-inches

Lake Union Tunnel Regulator Station. The Lake Union tunnel regulator station would be located in the Lake Union tunnel at 8th Avenue North and Republican Street. The regulator would divert flows from the Lake Union tunnel to the Mercer Street tunnel during storm events. The regulator station would be a reinforced concrete structure. This regulator station would contain one gate to the Lake Union tunnel and cause an overflow into the 72 to 84-inch-diameter Lake Union tunnel CSO pipeline. The control signals would be generated as a result of information transmitted from sensors at the Denny regulator station.

Lake Union Tunnel CSO Pipeline. The Lake Union tunnel CSO pipeline would be a 72 to 84-inch pipe extending approximately 740 feet from the Lake Union tunnel regulator station to the east portal and drop structure at the east end of the Mercer Street tunnel. The pipeline would be constructed beneath the easternmost lanes of 8th Avenue North, which was selected as the pipeline alignment following evaluation of five alternatives. It is a wide, two-way street, and construction there would result in fewer utility conflicts, business impacts, and disruption to traffic than the other alignments considered.

South Lake Union CSO Pipeline: The south Lake Union CSO pipeline would be a 72 to 84-inch pipe to connect the City of Seattle Phase 2 pipeline at the Valley Street connection to the east portal and drop structure. Following evaluation of three alignment alternatives, it was determined that direct alignment using trenchless technology would provide the fewest impacts.

Central Trunk Diversion Structure: The Central Trunk diversion structure would be constructed of concrete and divert wastewater from the Central Trunk sewer to the Mercer Street tunnel during periods of high flow in the Central Trunk. This below-grade, reinforced concrete structure would be located just south of Roy Street on Dexter Avenue North and discharge into the Central Trunk CSO pipeline. The structure would be constructed as a side weir, with 20-foot long, adjustable height weirs located on both sides of the Central Trunk pipeline. The weirs would be set approximately 1.83 feet above the pipeline invert. The weirs would be designed to provide adjustment in either direction from the initial elevation to allow tuning for compliance with regulatory requirements. Flows spilling over the weir will enter the Central Trunk CSO Pipeline for conveyance to the Mercer Tunnel.

In this configuration, flow would begin to be diverted to the Central Trunk CSO pipeline, and on to the Mercer Tunnel, at a flow of approximately 27 mgd. At a Design Storm 6 Central Trunk flow of 57 mgd, approximately 18 mgd would be diverted to the Mercer Tunnel. At a November 1978 Storm flow of 136 mgd in the Central Trunk, approximately 56 mgd would be diverted to the tunnel.

Central Trunk CSO Pipeline: The 300-foot-long Central Trunk CSO pipeline would be a 54-inch-diameter pipe, minimum. It would convey overflows east under Roy Street from the Central Trunk Diversion Structure to the east portal and drop structure.

The size and slope of the Central Trunk CSO Pipeline will be finalized during final design. A 54-inch pipe would provide sufficient capacity to carry the maximum expected Central Trunk flow of 136 mgd (November '78 storm) while being only two-thirds full. This pipeline may be constructed by open cut or microtunneling techniques. Larger pipe diameters may be selected by the Contractor to take advantage of economics resulting from using the same size TBM for all of the pipelines. The design currently illustrates a 72-inch pipe, consistent with all other pipes for the South Lake Union CSO Control Facilities.

Lake Union Tunnel Regulator Station: Like the other Denny Way/Lake Union CSO Control Project system components, the south Lake Union CSO pipelines, diversion structure, and regulator station are intended as storm weather facilities only.

Dry weather flows would be accommodated in the existing collection, interceptor, and trunk systems. No flow would be diverted by the regulator or diversion structure during dry weather flow periods. However, flow would begin to be diverted to the Mercer Street tunnel at a flow rate of 38 mgd if the regulator is not closed.

During storm periods, when an overflow at the Denny regulator station becomes imminent, the gates in the Lake Union tunnel regulator station would close. This would, in turn, direct flows into the Lake Union tunnel CSO pipeline, which would convey those flows north to the Mercer Street tunnel. The design flows for the Lake Union tunnel are 58 mgd (Design Storm 6) and 116 mgd (November 1978 storm). The gate will close once the Denny regulator gates close and would remain closed even under emergency conditions. Flow diverted from the Lake Union tunnel would mix with combined wastewater collected by the City of Seattle at the east portal. Similarly, as flows increase in the Central Trunk CSO pipeline, flows at the Central Trunk diversion structure would likewise be directed to the east portal and drop structure for storage in the Mercer Street tunnel.

Construction Considerations: Information concerning subsurface conditions in the project area is limited. Soil conditions along the pipeline routes and at each of the major structures would need to be determined during design.

In order to minimize traffic disruptions on Valley Street, Broad, Westlake, Mercer Street, and 9th Avenue North, the South Lake Union CSO pipeline would be constructed using trenchless methods. The areas in which the construction will occur are heavily congested, and the sequence and timing of construction will need to consider both commuter traffic impacts and special event needs. Trenchless methods would also be employed for the continuation to the east portal and drop structure due to the depth of the pipeline. The Lake Union Tunnel CSO pipeline would also be constructed using trenchless methods as pipeline depths are between 40 and 50 feet. The Central Trunk CSO pipeline could be constructed using conventional construction methods or trenchless methods. No specific special requirements have been identified for the pipeline or buried structures beyond normal practices. Structural design of the diversion and regulator structures would conform to typical practices for buried structures.

Other design and construction considerations include:

- Odor control. Odor control would not be required.
- Architecture. No architectural issues need to be addressed, as all structures would be below grade.
- Electric power. Electric power to operate the Lake Union tunnel regulator gates would be provided from a local transformer.
- Staging area. Storage for pipeline material and tunnel boring equipment would be needed.
- Surface restoration. Paved and concrete surfaces must be restored according to City standards.
- Landscaping. All affected existing landscaped areas must be restored. No new landscaping is proposed.
- Utility conflicts. No major utility conflicts have been identified.
- Standby power. Standby power would not be required for the Lake Union tunnel regulator. A stored-energy device to operate gates and controls during power outages is being considered.

Cultural resources. Monitoring of all areas with a high potential for cultural resources (historic and archaeological) must be undertaken during construction.

10.3.2 Seattle Valley Street Connection and Conveyance Facilities

Valley Street Connection: The Valley Street connection would be a 60 to 72-inch, pipe extending approximately 800 feet from an existing weir at Valley Street just east of Fairview Avenue North to the South Lake Union CSO Pipeline. The pipeline may be constructed using open cut or microtunneling techniques. The weir was built near the downstream end of the Phase 1 pipelines and will split low flows from storm flows. Low flows would continue through the existing system to the Lake Union Tunnel, while storm flows would be conveyed to the east portal and drop structure. The pipeline would cross the Fairview and Valley intersection and continue along Valley Street, staying north of the travel lanes (see Figure 10-20).

CSO #175: CSO #175 is approximately 1,950 feet of 12- to 30-inch pipe that would convey flows from Lakeview Boulevard East at the existing overflow weir to the Phase 1 pipeline in Eastlake Avenue East. The pipeline would convey all flows from this sub-basin under the west side of Lakeview Boulevard East heading north, turn west to cross under the elevated structures of I-5, and continue under East Galer Street to Eastlake Avenue East. The overflow weir would be abandoned and CSO #175 will be eliminated. Figures 10-21, 10-22, 10-23, and 10-24 show this pipeline routing.

***CSO #125*:** Usage of CSO #125 was substantially reduced by construction of Phase 1. After substantial completion of the new Phase 3/4 facilities, it will be eliminated. The outfall pipe is exposed and discharges near shore. The exposed section will be cut off on shore and removed. Sewers no longer in use would be abandoned.

10.3.3 Denny Area Conveyance Facilities

The Denny area conveyance facilities would connect the downstream end of the existing Lake Union tunnel to the proposed Elliott West CSO control facility. CSOs that currently overflow at the Denny regulator during storm events would be intercepted upstream of the regulator and conveyed to the Elliott West CSO control facility site for storage and/or treatment onsite. Flows in excess of the storage capacity of the Mercer Street tunnel would be treated and conveyed back to the vicinity of the Denny regulator station for discharge to Elliott Bay through the new Elliott West outfall. The design information for the Denny Area conveyance facilities is summarized in Table 10-5.

Table 10-5
Denny Area Conveyance Facilities

Pipeline	Diameter	Slope	Full Pipe Velocity (fps)	Flow (mgd)	n-value
Elliott West CSO Pipeline	72-inch	0.0014	5.31	150	0.013
Elliott West Effluent Pipeline	96-inch	0.0004	7.54	379	0.013
System Drain	84-inch	0.0013	7.59	292	0.013

Denny Way Diversion Structure: The Denny Way diversion structure will eliminate many of the combined sewer overflows from the existing outfall that resulted from exceeding the capacity of either the Elliott Bay Interceptor (EBI) or the 30-inch connector line between the EBI and the Denny Way Regulator. Only excess flows associated with storms events which exceed the design storm (1 discharge per year) will continue to flow untreated to Elliott Bay from the Lake Union and Local pipelines through the existing Denny Regulator. Flows that cause the level in the new Diversion Structure to exceed the weir setpoint will spill over a sidespill weir into the CSO Pipeline for conveyance to the Elliott West CSO control facility.

The Denny Diversion Structure is an approximately 40-foot long by 18-foot wide by 15-foot deep reinforced concrete structure. This subsurface, cast-in-place structure would be constructed around, and incorporate, the existing 42-inch Denny Local and 60-inch Lake Union trunk lines east of the existing Denny Regulator and west of the Burlington Northern Santa Fe railroad right-of-way (BNSFRR) fence at Alaskan Way. The structure will be pile-supported, to reduce potential settlement and avoid possible overexcavation of contaminated materials. A total of seven 40-ton augured piles are anticipated, with tip elevation at 70-foot. Proposed piles and structural design will be refined during final design based on more recent geotechnical information than was available at the time of preliminary design.

It is anticipated that the Denny Diversion Structure will include level sensing devices utilizing compressed air originating within the existing Denny Regulator Building. Three compressed air pipelines are expected to be required within the Denny Diversion Structure, one on the upstream side of each of the two side-spill weirs, and one in the common channel on the downstream side of the weirs. With the exception of the level sensors, there will be no mechanically or electrically operated devices in the Denny Way diversion structure.

Wastewater from the Lake Union tunnel and Western Avenue and lower Queen Anne areas is currently conveyed to the Denny Way regulator station by means of a 60-inch pipe (the Denny/Lake Union pipeline). Combined wastewater from the area east of Elliott Avenue West and north of Denny Way to about Queen Anne Avenue (the Denny local area) is conveyed through a 42-inch pipeline (the Denny local pipeline) running side by side with the Denny / Lake Union pipe. The two pipelines flow through separate regulators at the Denny Way regulator station into a single, 30-inch header pipe, which empties into the EBI. The constriction of flows into the smaller pipe results in overflows at Denny during periods even when there is remaining capacity in the EBI to receive the flows from the Denny / Lake Union and Denny local areas.

The emergency overflow weir for the Denny / Lake Union pipeline in the Denny Way Regulator is set at an elevation of 111.5-feet, and the emergency overflow weir for the Denny local pipeline is set at an elevation of 107-feet. The Denny Way diversion structure would also contain weirs for each of the pipelines. Each of those weirs would be set approximately 1.5-feet below the corresponding regulator station weir elevation, or at 110.0-feet for the Denny / Lake Union pipeline and 105.5-feet for the Denny local pipeline. With the new diversion structure in place, overflows that have previously resulted from the flow restriction would be diverted into the Elliott West CSO pipeline for conveyance to the Elliott West CSO control facility.

Denny Area Pipelines: Two large pipelines would need to be constructed to regulate flows among the new and existing facilities between the Denny Way regulator station and the Elliott West CSO control facility. The Elliott West CSO pipeline consists of approximately 2,600 lineal feet of 72- to 84-inch diameter pipeline, approximately 200-lineal feet of 96-inch diameter pipeline (under the railroad tracks), and approximately 200 lineal feet concrete box (from the Denny Diversion Structure to west of the EBI). The CSO Pipeline would carry overflows from the Denny Way diversion structure to the EBI Control Structure. A new 96-to 108-inch-diameter Elliott West effluent pipeline would convey partially treated effluent from the Elliott West CSO control facility to the new Elliott West outfall. In addition, a 2-inch-diameter, 3,100-foot long pipeline would be required to transport dechlorinating chemicals from the Elliott West CSO control facility to the Dechlorination structure, where the dechlorination chemical (sodium bisulfite) would be injected just upstream of the outfall pipe. The 2-inch pipe would be double walled PVC pipe to protect against chemical leaks, and would be designed to minimize the potential for “freezing” of the chemical solution, which begins to crystallize when the temperature falls below 43^{o} F. Several additional smaller diameter pipelines will be required as part of the Denny Area Conveyance Facilities. These include: compressed air supply and sensing lines for bubbler systems; a trash pump discharge line from the Elliott West Control Facility site to the EBI Control Structure; and an 18-inch air vent line from the Effluent Pipeline Drop Structure to the Elliott West CSO Control Facility site (terminating above the effluent channel maximum HGL). The BNSFRR requires that all pipelines under its tracks be designed to meet special loading requirements (i.e., AREA Cooper E-85 loadings must be used).

Three corridors were considered for locating the Elliott West CSO pipeline and the Elliott West effluent pipeline: (1) Elliott Avenue West, (2) along the existing EBI in the BNSFRR right-of-way, and (3) along the western edge of the Cargill grain terminal compound and within the Alaskan Way right-of-way within Myrtle Edwards Park.

The project team developed and evaluated nine alternative alignments for the Denny area pipelines in these three corridors using trenchless and / or open cut construction. The nine alternatives were subject to three stages of evaluations: fatal flaw analysis; cost; and non-cost criteria. One alternative placing both pipelines in a single trench along the Elliott Avenue West right-of-way was eliminated in the fatal flaw analysis because of limited space available in Elliott Avenue West, south of the Elliott / Western intersection. The remaining eight alternatives were evaluated in terms of the cost and non-cost criteria. Based on the cost criteria, three additional alternatives were eliminated. The five alternatives considered in more detail are:

Alternative 1 Alternative 1 would place the Elliott West CSO pipeline along BNSFRR R.O.W. using trenchless technology, with the Elliott West effluent pipeline constructed along Elliott Avenue West using an open cut trench.

Alternative 2 Alternative 2 would place both pipelines along the western edge of the Cargill grain terminal compound and within the Alaskan Way R.O.W within Myrtle Edwards Park using an open cut trench.

Alternative 3 Alternative 3 would place the Elliott West CSO pipeline in open cut trenches along Elliott Avenue West, with the Elliott West effluent pipeline in an open-cut trench in Myrtle Edwards Park.

Alternative 4 Alternative 4 is the reverse of Alternative 3, with the Elliott West effluent pipeline in an open cut trench along Elliott Avenue West and the Elliott West CSO pipeline in an open cut trench in Myrtle Edwards Park.

Alternative 5 Alternative 5 places the Elliott West CSO pipeline along the BNSFRR R.O.W. using a trenchless technology, with the Elliott West effluent pipeline in an open-cut trench in Myrtle Edwards Park.

The non-cost evaluation included hydraulics, operation and maintenance impacts, schedule impacts, constructibility / risk, permitting impacts, right-of-way impacts, Mercer Street tunnel interface, and traffic impacts. The non-cost evaluation identified Alternative 2 as the preferred alternative.

Constructability / risk was an important non-cost criterion. Photos taken during EBI construction show that large riprap was encountered along the BNSFRR R.O.W. Field investigation conducted by the design team indicated that this riprap might have been moved into the fill between the rail yard and the EBI. Alignments 1, 4, and 5 were eliminated from further consideration due to the large risk associated with construction in the BNSFRR R.O.W. with the likely presence of the riprap.

Traffic impacts were also an important non-cost criterion. Elliott Avenue West is very congested, with a traffic volume of 900 vehicles per lane in peak directions. City policy requires that traffic volumes not exceed 650 vehicles per lane during construction periods. Preliminary analysis indicates that the contractor would be limited to 4 hours of work per day under these restrictions. Since construction of

Alternative 3 would likely require two lanes, nighttime construction would be necessary, increasing construction cost and causing scheduling problems. Due to these restrictions, Alternative 3 was eliminated from future consideration.

Alternative 2 was identified as the preferred alternative. The two advantages of Alternative 2 are that only one trench would be required since the two pipelines would be constructed along the same corridor, and the soil conditions are relatively good. However, Alternative 2 requires the Elliott West CSO pipelines to cross the west side of the EBI and might require a hydraulic connection to the EBI. This interconnection would reduce the hydraulic grade line slope for the Elliott West CSO pipelines, thereby requiring a larger diameter pipe to convey flows, and could diminish capacity of the existing EBI. Therefore, it is suggested that the Elliott West CSO pipelines cross the EBI without a hydraulic interface.

Two sub-alternatives within Alternative 2 were evaluated (2A and 2B). In both alignment alternatives, the Elliott West CSO pipeline crosses beneath the EBI at the north end. At the south end, in Alternative 2A, the Elliott West CSO pipeline crosses the EBI with a shallow concrete box. In Alternative 2B, the south end of the Elliott West CSO pipeline crosses over an existing 30-inch pipeline connecting to the existing Denny regulator and under the existing 96-inch Denny Way CSO outfall. Alternative 2B was deemed to be not feasible because the existing 96-inch outfall is constructed in steel pipes, obstructing the proposed alignment. Alternative 2A is illustrated in Figures 10-26, 10-27, 10-28, and 10-29.

EBI Control Structure and System Drain: The EBI control structure will be a cast-in-place, below grade, reinforced concrete structure constructed over the existing EBI. The purpose of the structure is to divert excess storm flows from the EBI and the Denny Way diversion structure to the Elliott West CSO control facility and to release stored flows from the Mercer Street tunnel into EBI for conveyance to West Point for treatment.

Flows to and from the EBI control structure would be conveyed through an 84 to 96-inch-diameter system drain pipeline between the EBI control structure and the Elliott West CSO control facility. The final control structure location has not been determined.   The control structure may be located several hundred feet south of the Elliott West Control facility so that the structure would be located west of the railroad, rather than between two sets of tracks as depicted in the current design configuration.

Facility Operation. Like the other Denny Way / Lake Union CSO Control Project components, the Elliott West CSO pipeline, effluent pipeline, EBI Control Structure, and the Denny diversion structure are intended for storm-weather operation only. Dry weather flows